Journal of the Royal Society of Western Australia, Vol. 67, Parts 3 and 4, 1985, p. 109-115.

The Becher Sand, a new stratigraphic unit for the Holocene of the Perth Basin

by V. Semeniuk[1] and D. J. Searle[2]

[1] 21 Glenmere Road, Warwick, W.A. 6024.
[2] 108 Dalkeith Road, Nedlands, W.A. 6009.

Manuscript received: 6 November 1984; accepted: 15 April 1985.

Abstract

The term Becher Sand is proposed for the sequence of Holocene sediments comprised predominantly of homogenous to bioturbated sand and muddy sand that occurs along the coastal zone of the Swan Coastal Plain. The sediments are in part contemporary and also occur in subcrop. The sediments have formed mainly as submarine seagrass bank sequences. The Becher Sand was formerly part of the Safety Bay Sand and separation of the new formation will significantly clarify formational relationships and Holocene history in the coastal zone.

Introduction

The coastline of southwestern Australia is comprised of a number of Quaternary lithostratigraphic units of which the Tamala Limestone and Safety Bay Sand are the most widespread. The stratigraphy of coastal areas frequently records a complex coastal history and reflects variation in sedimentation style, supply, climate, tectonism and eustatism. The identification of distinct stratigraphic units therefore is an important prerequisite to describing and unravelling coastal history because it is only with the recognition of lithofacies, unconformity and sealevel markers that a realistic reconstruction of palaeo-environments, sealevel fluctuations and intervals of subaerial exposure can be achieved. To this objective for instance it is important to be able to recognise lithofacies that have environmental significance in term of

- precise sea level indicators e.g. beach sequences
- occurrence as a lithotope, e.g. seagrass bank sediments
- terrestrial conditions e.g. lacustrine sediments
- subaerial exposure e.g. soils
- water table and vadose conditions e.g. calcrete or sparry calcite cements
- shoreline conditions e.g. rocky shore sequences

To date a number of papers have described and defined Quaternary stratigraphic units and in particular Holocene stratigraphic units in the Perth Basin, that are important to understanding coastal history. These works include: Passmore (1970) who described the "Coastal Limestone" (= Tamala Limestone), Cooloongup Sand and the Safety Bay Sand in the Rockingham district; Fairbridge (1950, 1953) who described the "Coastal Limestone" at Point Peron as well as the Peppermint Grove Limestone and Rottnest Limestone; Playford *et al.* (1976) who reviewed and summarised the stratigraphic information up to 1975; Playford and Leech (1977) who described the Quaternary Stratigraphy of Rottnest Island; France (1978) who described Holocene barrier and fringing seagrass banks of Cockburn Sound; Semeniuk (1983) who described the Eaton Sand, Leschenault Formation and Australind Formation and subdivided the Safety Bay Sand in the Leschenault Peninsula area; Semeniuk and Johnson (1982) who described beach/dune sequences, Woods (1983) and Woods and Searle (1983) who described stratigraphic sequences under prograded plains; and Semeniuk & Searle (1985) who described Holocene aeolian, beach and sublittoral sands as a framework to studies on calcrete.

In the course of stratigraphic studies along the coastline of southwestern Australia it has become evident that the original concepts of the Safety Bay Sand as defined by Passmore (1970) include two distinct lithologic units that have formed in separate environments and that have distinct palaeo-environmental implications. It is the purpose of this paper therefore to describe these differences between these units and to establish a new formation within Holocene sequences of the Swan Coastal Plain, Perth Basin.

Geological setting

The study area is set along the coastline and nearshore marine environment of the Rottnest shelf (Carrigy & Fairbridge 1954) of southwestern Australia, where contemporary sediments of the modern Perth Basin are accumulating (Fig. 1). This coastal system is composed of Holocene sediments as well as erosional surfaces cut into Pleistocene materials, and is the seaward extremity of the Swan Coastal Plain, a Quaternary sedimentary system of the Phanerozoic Perth Basin (Playford *et al.* 1976). Along this shoreline the Spearwood Dune (= Tamala Limestone) and Quindalup Dune systems constitute the dominant landforms. Localised sediment accretion together with erosion of the partially inundated Pleistocene aeolianite-ridge topography has developed a complex array of coastal components as described in Searle & Semeniuk (1985).

The most important sites of sediment accumulation along the coast occur in the Cape Bouvard-Trigg Island sector. This sector is characterised by a series of parallel offshore and onshore limestone ridges in various stages of erosional degradation. Accumulation of Holocene sediment in this sector has been mainly restricted to loci termed accretionary cells, in zones of wave energy shelter behind prominences (reefs, cays, islands) of the first offshore ridge (Searle 1984, Searle & Semeniuk 1985). Similar accretionary sites occur in discrete coastal cusps in the adjoining coastal sectors to the north from Whitfords Point to Jurien Bay.

Accretion in the loci begins with shoaling and prograding of a submarine bank, in most cases under a cover of seagrasses. Eventually the bank forms a submarine barrier or sill spanning the depression from

the offshore ridge to the shore. This initiates progradation of beach, beachridge, and dune sediments, across the submarine bank top to form a growing cuspate promontory. The various banks and submarine sandy promontories in a given area may represent various stages of development of these accretionary cells (Searle 1984). In the Bouvard-Trigg sector, Rockingham and Becher promontories

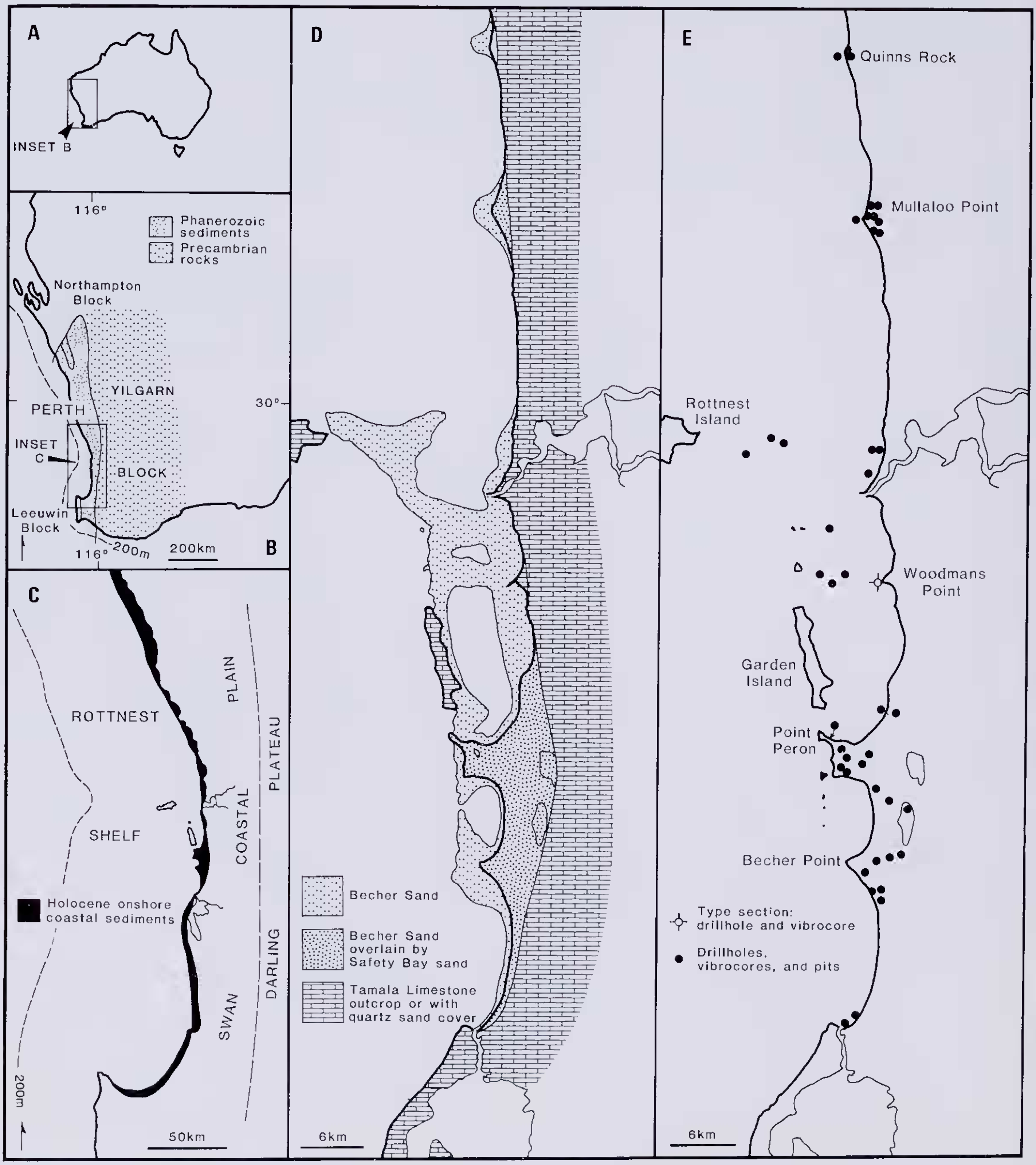

Figure 1.—A and B.—Location of study area within Perth Basin. C.—Distribution of Holocene sands along the coast zone of the Swan Coastal Plain. D.—Contemporary distribution and subcrop distribution of Becher Sand in the Cape Bouvard-Trigg Island sector of the Rottnest Shelf coast. E.—Location of type section and other drill holes that intersect Becher Sand. Drill holes from Passmore (1970), Woods and Searle (1983), Searle (1984) and this paper.

have achieved final stage of accretion (i.e. "island-capture"), Parmelia and Success banks have achieved the submarine barrier stage, and Fairway Bank is still in the initial stages of submarine bank growth. The fully developed stratigraphic sequence produced in these loci is:

top:
- aeolian sands
- beach/beach ridge sediments
- seagrass bank sediments
- unconformity

bottom:
- Pre-Holocene sediments

It is this sequence of Holocene sediments that forms the subject matter of the present paper.

Previous work on Safety Bay Sand

Passmore (1970) defined the Safety Bay Sand as the "fine to coarse grained calcareous sand consisting in most places of more than 50% skeletal fragment of marine organisms and lesser amounts of quartz grains. The upper part is buff-colored beach and dune sand while the lower part is grey marine sand. The formation forms the land surface of almost all of the Rockingham and Cape Peron peninsulas, and includes modern shallow water marine and dune sands of similar composition". This original definition obviously included submarine seagrass bank sand, beach sand and aeolian sand.

At a later stage Playford and Low (1972) in a revision and formal definition of Perth Basin Quaternary units reapplied the term Safety Bay Sand to include dune, beachridge, strand and shallow marine sediments and extended the formation to encompass all similar deposits along the Perth Basin Coastline. The only other stratigraphic work on the Safety Bay Sand was carried out by Semeniuk (1983) who subdivided the formation in the Leschenault Peninsula area into several members based on lithologic and diagenetic criteria and relationship of units to mean sealevel.

Rationale for new stratigraphic unit

Holocene marine and coastal sediments along the nearshore and coastline of southwestern Australia are predominantly of two types—

a beach-beachridge-dune suite that forms a genetically internally related shoaling package
a seagrass bank suite

The beach—beachridge—dune suite forms a blanket to prism-like body. The small scale stratigraphic sequence within the suite has been described by Semeniuk & Johnson (1982). This suite of sediment may occur as a capping to submarine sands, or may occur as a shoestring body adjacent to Tamala Limestone shore/cliff, or may occur as a unit encroaching over varied terrain such as Tamala Limestone ridges, wetlands or lagoons. The sediment types in this suite contain distinct sedimentary structures, which are formed by wave action, aeolian and pedogenic processes, and sedimentary textures (Table 1). The sedimentary structures are sufficiently diagnostic to be useful indicators of subaerial conditions, tide levels and mean sealevels (Semeniuk & Johnson 1982).

On the other hand, the sediment comprising the submarine (seagrass) banks generally all form mound-like bodies. The sediments are relatively more homogeneous due to the nearly pervasive imprint of bioturbation and root structuring (Table 1). These sediment bodies overlie submarine unconformities or overlie submerged terrestrial unconformities. The sediments may be capped by a beach-dune sequence or they may be still developing and thus are at a contemporary seagrass bank stage.

In terms of sand grain composition the seagrass bank sediments are similar to those of the beach-beachridge-dune suite and in fact they supply such grain types to the strand environment. However, in terms of sedimentary processes and products as expressed in sedimentary structures, grain sorting and range of grain sizes, and in terms of diagenetic processes as expressed in sediment colour, cementation, solution, and humification, the two sedimentary suites are readily and consistently distinguishable. The units thus satisfy the requirements to be viewed as separate formations in that both possess some degree of lithologic homogenetity, particularly in the type of primary sedimentary structures, as well as textural components and colour. These differences are sufficiently distinct to enable the two units to be mapped separately and thus satisfy the requirements for formational status (Hedberg 1976, North American Commission on Stratigraphic Nomenclature 1983).

Cleary therefore there are two obvious mappable Holocene litho-stratigraphic units along southwestern Australia and each unit is indicative of specific environments. If these units are left unidentified within a framework of "Safety Bay Sand" as presently defined, the clarification of Quaternary stratigraphic relationships and coastal history would be diminished.

Description of Becher Sand

The Becher Sand is the name proposed for the sequence of grey structureless to bioturbated, fine and medium quartzo-skeletal sand with lesser muddy sand, layered mud and seagrass peat that underlies modern (contemporary) seagrass band and prograded coastal plain sequences. Its name is derived from nearby Becher Point, south of Warnbro Sound, where contemporary seagrass mound-like sediment bodies are accumlating (grid reference 370998 Pinjarra 1:250 000 sheet).

Type Section: Core site at Woodmans Point (grid references 374026 Pinjarra 1:250 000 sheet) through the Parmelia (Seagrass) Bank is designated as the type section (Fig. 1). Material from the core has been lodged with the Geological Survey of Western Australia. The sequence within the type section is described in Table 2.

Distribution: The Becher Sand has been intersected in numerous cores and its distribution, both currenty depositional (contemporary) and subsurface is widespread (Fig. 1).

Table 1

Characteristics of Becher Sand and Safety Bay Sand

Formation and their facies suite	Litho-tope unit	Subdivisions	Lithology	Geometry	Large structures	Small structures	Texture	Colour
Beach-Beach Ridge-Dune Suite = Safety Bay Sand	Dune	mobile dunes	laminated quartzo calcareous sand with local soil sheets	wedge to prism to blanket to shoe-string	large scale cross layering	cross-layering	fine and medium sand	buff-cream
		vegetated dunes			large scale cross layers; bioturbated-homogeneous layers	cross-layering		buff-cream
		soils			homogeneous	Homogeneous, root structured, bioturbated	fine and medium sand with humus	buff-cream
	Beach Ridges	mobile			large scale cross layering	cross layering	fine and medium sand	buff-cream
		vegetated			large scale cross layers; bioturbated-homogeneous layers	cross layering; root structured, bioturbated at surface		
	Beaches	backshore	laminated quartzo calcareous sand locally shelly	sheet to ribbon	horizontal layering	Cross layering, bioturbated; homogeneous; horizontal layering	medium and coarse sand with shell	buff-cream
		foreshore			inclined layering	fine lamination and vesicular structure	medium and coarse sand; shell	buff-cream
		shoreface			horizontal and cross layering	trough cross layering	gravel to coarse to fine sand	buff-cream
Sea-grass Bank Suite =Becher Sand	No sub-division	bank crest	structure-less quartzo calcareous sand and muddy sand, and mud	prism to wedge	structureless	bioturbated to homogeneous to root structured	fine, medium and coarse sand, locally muddy, locally shelly	grey to cream
		bank slope			structureless to crudely layered	bioturbated to layered		grey to

Table 2

Description of type section at Woodman's Point*

top:	Safety Bay Sand	laminated buff medium, coarse and fine carbonate/quartz sand, very shelly	2 m
			water table
		bioturbated to structureless fine to medium grey carbonate/quartz sand, very shelly with seagrass rhizomes and roots locally with muddy sand layers	1 m
		bioturbated to crudely layered fine to coarse grey carbonate/quartz sand, very shelly	2 m
	Becher Sand	bioturbated to structureless fine to medium grey carbonate/quartz sand few shells; some coarse sand layers	3 m
		bioturbated to structureless fine to coarse grey carbonate/quartz sand, shelly with seagrass fibre	3 m
		fine to very coarse grey carbonate/quartz sand, shelly	1.5 m
		fawn coloured mud with seagrass fibre	0.5 m
	Unnamed Unit	peat and wood	0.5 m
base:	Tamala Limestone	calcreted aeolianite limestone	0.5 m and end of hole

* Based on vibrocore for upper 12 m and reverse circulation air-core for remainder of section.

Geometry and Thickness: The formation is over 20 m thick under the coastal plain in the Rockingham area; elsewhere the formation is generally 10-15 m thick. In localities where it is a contemporary and depositional the unit forms mound-like bodies standing with up to 10-22 m in relief above the adjoining basin depression floors. Where it has prograded and shoaled, as in the Becher Point—Rockingham Plain area, it forms a seaward thickening wedge body, triangular to rectangular in plan.

Lithology (Fig. 2): The dominant sediment type in the formation is a grey, structureless to bioturbated, medium and fine sand composed of quartz and skeletal grains. Locally there are shell gravel layers, coarse sand layers, calcareous muddy sand (packstone), calcareous mud layers that may be laminated, seagrass rhizome horizons, seagrass peat and laminated sand.

Stratigraphic relationships (Fig. 2): The formation overlies the following units:

1. Tamala Limestone (sharp unconformable contact)
2. Cooloongup Sand (bioturbated to gradational unconformable contact)
3. Calcareous muds of deeper water submarine depressions (conformable contact)
4. Calcareous/terrigenous muds of the Leschenault Formation (conformable contact)

The formation may be overlain by the laminated sediments of the Safety Bay Sand and the contact is conformable and mostly sharp. In addition the formation interdigitates with contemporary lateral facies such as deeper water basin muds.

Age and fossils: The Becher Sand is wholly Holocene. Radiocarbon ages from shells within the unit all give ages less than 7 000 years (Searle 1984, Woods & Searle 1983, and this paper). Fossils collected from the formation include:

Foraminifera: *Marginopora vertebralis, Discorbis vesicularis, Peneroplis planatus;* Bivalvia: *Anodontia perplexa, Brachidontes ustulatus, Callucina lacteola, Chioneryx cardioides, Divalucina cumingi, Donax francisensis, Electroma georgiana, Eucrassatella sp, Glycymeris striatularis, Gomphina undulosa, Hemidonax chapmani, Irus distans, Mactra australis, Mactra matthewi, Mysella sp, Saccostrea cucullata, Paphies cuneata. Pinna sp, Tawera coelata, Tawera lagopus, Tellina tenuilirata, Thraciopsis subrecta, Wallucina cf jacksoniensis;* Gastropoda: *Acteocina sp, Amalda monilifera, Amblychilepas oblonga, Astralium squamiferum, Bedeva paivae, Bittium granarium, Bulla quoyii, Calyptraea calyptraeformis, Cantharidus (Phasianotrochus) irisodontes, Cantharidus (Phasianotrochus) sp, Clanculus sp, Cominella tasmanica, Conus anemone, Dicathais orbita, Drupa sp, Ethminolia vitiliginea. Gibbula (Notogibbula) lehmanni, Gibbula preissiana, Haminoea brevis, Hipponix conicus, Hipponix foliaceus, Leiopyrga octona, Mangelia sp, Mitrella (Dentimitrella) austrina, Mitrella (Dentimitrella) menkeana, Naccula punctata, Natica sp, Collisella onychitis, Notocochlis gualteriana, Notomella bajula, Oliva australis, Parcanassa sp, Phasianella australis Phasianella solida, Phasianella ventricosa, Polinices conicus, Proterato sulcerato, Pyrene scripta, Syrnola sp, Thalotia (Prothalotia) lehmanni, Thalotia (Prothalotia) pulcherrima, Thalotia (Odontotrochus) chlorostoma, Turbo intercostalis, Tanea sagittata, Vexillum marrowi, Zafra vercoi;* and Bryozoa: *Rhynchozoon* sp. (commonly in colony form wrapped around former *Amphibolus* seagrass stems) and other species. In addition there are numerous traces of crustacean burrows, seagrass rhizomes, and, locally, seagrass leaves.

Discussion

The separation of the original Safety Bay Sand into two units, an upper, laminated to cross-laminated unit (related to beach, beachridge and dune systems) and a lower structureless unit (related to seagrass systems) recognises the inherent lithological differences between these two units as reflected by primary sedimentary structures and textures. The Safety Bay Sand thus is retained for the upper unit which crops out and forms the contemporary aeolian,

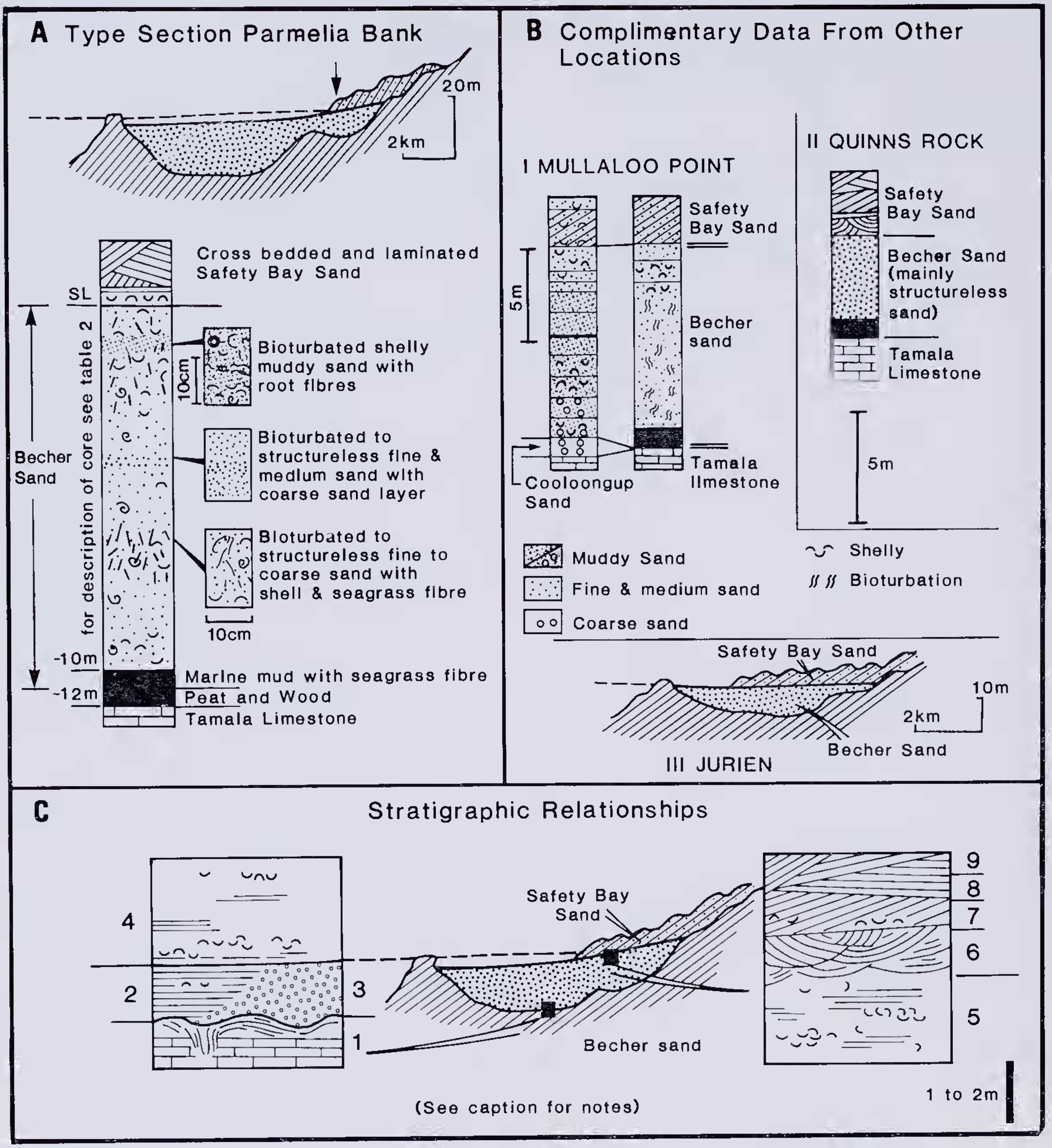

Figure 2.—A.—Details of profile along the type section of Becher Sand at western tip of Woodmans Point. B.—Complementary stratigraphic information on Becher Sand from other localities. C.—Details of stratigraphic geometry, and types of contracts at base and top of Becher Sand.

Key to units is as follows:
(1) Becher Sand with minor amount of bioturbation mixing with underlying mud and quartz sands. (2) Leschenault Formation and/or undifferentiated marine muds grading laterally to (3) quartzose Cooloongup Sand. (4) Tamala Limestone with calcrete capstone and calcrete-lined solution pipes (5) to (8) Safety Bay Sand showing a well defined sequence of aeolian cross-bedding; shallowly seaward or landward dipping lamination and bedding, more steeply seaward dipping lamination; and complex trough cross-bedding. (9) largely structureless Becher Sand with occasional zones of lamination and discontinuous shell lag horizons.

beachridge and beach systems of the coast. In effect the Safety Bay Sand becomes coincident with the Quindalup Dunes of McArthur & Bettenay (1960). The term Becher Sand is given for the lower unit which forms the contemporary submarine sand promontory and seagrass systems of the coast and extends beneath the coastal plain.

As defined herein the formations should clarify studies of stratigraphic relationships and coastal history in that workers in the Holocene can now identify and map out the distinct sediment bodies. Dune fields encroaching shoreward upon subaerial limestone terrain can be viewed as systems where Safety Bay Sand is prograding over Tamala Limestone; beachridge/dune fields prograding seawards over seagrass banks can be viewed as systems where Safety Bay Sand is prograding over Becher Sand. Sand bodies that occur *below* the water table can be assigned either the Becher Sand *or* to the Safety Bay Sand; this will be important distinction (e.g. Semeniuk 1983) and will significantly clarify stratigraphic/history relationships in Holocene sequences.

Acknowledgements:—The manuscript was reviewed by Dr. A. E. Cockbain whose advice and discussions are gratefully acknowledged. Molluscs were identified by G. W. Kendrick and a bryozoan was identified by R. Wass; their help also is gratefully acknowledged. Funding for some of the core sites at Whitfords Point and Quinns Rocks was provided by Public Works Department of Western Australia and the Smith Corporation, respectively.

References

Carrigy, M. A. and Fairbridge, R. W. (1954).—Recent sedimentation, physiography and structure of the continental shelves of Western Australia. *J. Roy. Soc. W. Aust.*, **38**: 65-95.

Fairbridge, R. W. (1950).—The geology and geomorphology of Point Peron, Western Australia. *J. Roy. Soc. W. Aust.*, **34**: 35-72.

Fairbridge, R. W. (1953).—Australian stratigraphy: Perth, Univ. West. Australia Text Books Board, 516 p.

France, R. E. (1978).—The Sedimentology of Barrier and Fringing Banks in Cockburn Sound and the effects of Industrial Development on Sedimentation. Sedimentology and Marine Geology Group, Department of Geology, The University of Western Australia.

Hedberg, H. D., (ed.) (1976).—International Stratigraphic Guide. A guide to Stratigraphic classification, terminology and procedure. Wiley-Interscience.

McArthur, W. M. and Bettenay, E., (1960).—The development and distribution of soils of the Swan Coastal plain, Western Australia, CSIRO Soil Publ. 16, 55 p.

North American Commission on Stratigraphic Nomenclature (1983).—North American Stratigraphic Code. *AAPG Bull.*, **67**: 841-875.

Passmore, J. R. (1970).—Shallow coastal acquifers in the Rockingham District, Western Australia. *Water Research Foundation Australia Bull.*, **18**: 83 p.

Playford, P. E., Cockbain A. E. and Low, G. H. (1976).—Geology of the Perth Basin. *Geol. Surv. of W.A. Bull.*, **124**: 311 p.

Playford, P. E. and Leech, R. E. J. (1977).—Geology and hydrology Rottnest Island. *Geol. Surv. of W.A. Rept No.* **6**: 98 p.

Playford, P. E., and Low, G. H. (1972).—Definitions of some new and revised rock units in the Perth Basin: West. Australia *Geol. Survey Ann. Rept* **1971**: 44-46.

Searle, D. J. (1984).—Sediment transport system, Perth Sector Rottnest Shelf, Western Australia, unpub. PhD thesis Univ. of W.A.

Searle, D. J., and Semeniuk, V. (1985).—The natural sectors of the inner Rottnest Shelf coast adjoining the Swan Coastal Plain. *J. Roy. Soc. W. Aust.*, **67**: 115-135.

Semeniuk, V. (1983).—The Quaternary history and geological history of the Australind-Leschenault Inlet area. *J. Roy. Soc. W. Aust.*, **66**: 71-83.

Semeniuk, V., and Johnson, D. P. (1982).—Recent and Pleistocene Beach/Dune sequences, Western Australia. Sedimentary Geology, 32, 301-328.

Semeniuk, V., and Searle, D. J. (1985).—Distribution of calcrete in Holocene coastal sands in relationship to climate, southwestern Australia. Jnl Sed. Petrol., 55 (1), 86-95.

Woods, P. J. (1983).—Selecting a harbour site based on studies of coastal evolution and sedimentology at Jurien, Western Australia. South Austr. Conf. Coastal and Ocean Engineering Gold Coast, July, 1983.

Woods P., and Searle, D. J. (1983).—Radiocarborn Dating and Holocene History of the Becher/Rockingham Ridge Plain, West Coast, Western Australia. Search 14, 44-46.